DOCUMENT RESUME

ED 476 652 SE 067 972

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TITLE	Emergent Issues in Middle School Mathematics Action Research: A Meta-Analysis of Writing as a Pedagogical Strategy.
PUB DATE	2002-10-17
NOTE	26p.; Paper presented at the Annual Meeting of the Mid-Western Educational Research Association (Columbus, OH, October 17, 2002).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01/PC02 Plus Postage.
DESCRIPTORS	*Action Research; Mathematics Education; *Mathematics Teachers; Middle Schools; *Professional Development; Teaching Methods

ABSTRACT

This paper describes the concerns of four middle school mathematics teachers involved in a professional development program that allowed them the opportunity to conduct action research projects. The teachers chose to implement nontraditional writing activities in their instruction as part of their action research. The experiences, practices, and issues that emerged from the teacher-researcher's projects are discussed including issues that are common in research and those that are unique to research that involves the analysis of writing samples. The use of writing in mathematics classrooms has benefits for both students and teachers. Similar findings are discussed. An unexpected conclusion made by all of the teachers is that the greatest benefit of using writing is that it can create student-generated mathematical discourse. (Contains 20 references.) (Author)

Running Head: WRITING IN MATHEMATICS

Emergent Issues in Middle School Mathematics Action Research: A Meta-analysis of Writing as a Pedagogical Strategy

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Paper presented at the 2002 Annual Meeting of the Mid-Western Educational Research Association, Columbus, OH

October 17, 2002

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Abstract

This paper describes the concerns of four middle school mathematics teachers involved in a professional development program that allowed them the opportunity to conduct action research projects. The teachers chose to implement nontraditional writing activities in their instruction as part of their action research. The experiences, practices, and issues that emerged from the teacher-researcher's projects are discussed including issues that are common in research and those that are unique to research that involves the analysis of writing samples. The use of writing in mathematics classrooms has benefits for both students and teachers. Similar findings are discussed. An unexpected conclusion made by all of the teachers is that the greatest benefit of using writing is that it can create student-generated mathematical discourse.

Introduction

This qualitative study investigates the experiences of four middle school mathematics teacher-researchers engaged in action research as part of a professional development program. The focus of this paper is to examine the experiences, practices, and issues that emerged from the teacher-researcher's projects as they employed non-traditional writing activities in their mathematics classes.

Action research is a practice by which teacher-researchers have the opportunity to learn from and about their teaching. Through this methodology teacher-researchers can reflect, evaluate, and learn not only about their teaching, but also from their students. Conducting action research projects allows teacher-researchers to engage reflectively on their teaching and to explore issues of teaching and learning that are relevant to them. Engaging in action research can benefit all those involved in that it can bring self-renewal, and increase efficacy, morale, and student performance (Sagor, 2000). Researchers have found benefits of action research that increase a sense of professionalism for the teacher-researcher (Elliot, 1991; Smith, Layng, & Jones, 1996).

The teacher-researchers around whose experiences this discussion revolves were involved in a professional development program with a major urban midwestern research university. This program served as a master's degree program for some teachers, and as a professional development program offering graduate credit for those either not pursuing a master's degree, or those who had previously obtained a master's degree. The premise of the program was for the teachers to implement innovative practices in their teaching that coincided with current educational reform and conduct an action research project with the support of doctoral students and faculty from the university. This culminated in

a final (thesis) paper centered on their research. Collaborative efforts between teacher-researchers and universities as well as professional development programs such as this one serve to aid in teachers' pursuits of conducting research projects of their own, and thus creating a life-long process of inquiry for the teachers (Raymond & Hamersley, 1995).

The Project and the Teachers

I supported 4 of 13 mathematics teacher-researchers enrolled in a professional development program[1]. These four were in their data collection stages of their research, and I provided regular guidance in their data collection and analysis efforts for their action research projects. I was also a support person for one of the teachers (Iris) for the past year. I am a doctoral student in mathematics education and I was approached to participate in this program as part of the support team because my research interests (communication and mathematics) and experience would be useful to some of the teacher-researchers involved in the project.

As part of their participation in the program, all of the teachers in the program were assigned a support person, who was either a graduate student or a university professor. The support person helped them with planning and implementing instruction, as well as providing support and expertise in their action research endeavors. The teacher-researchers began the professional development program two years ago in order to learn more from and about their own teaching (and some for work towards a master's degree). Each teacher-researcher chose a topic and designed research questions that they would investigate throughout the duration of the program. The desire to change their

[1] The *Teacher-Researcher* Program supported by grants under the federally funded Dwight D. Eisenhower Professional Development Program, administered by the Ohio Board of Regents, and The Ohio State University/Urban Schools Initiative funded through the Jennings Foundation.

teaching practices drove their research questions, which in turn provided a theme for their instruction for the two years of the program.

For their action research projects, the teachers chose to implement writing in their mathematics classes using writing journals or expository writing exercises. The purpose of choosing writing in the mathematics classroom will be discussed later. Three of the teachers taught sixth grade mathematics and one taught eighth grade mathematics. The sixth grade teachers, Iris, Jean, and Amber, taught in urban schools, while the eighth grade teacher, Joanne[2], taught in a suburban school. Amber was the only teacher of the four who was working towards her master's degree. The other three were in the program to obtain graduate professional development credit. These four teachers have fewer than 10 years teaching experience. They chose writing in mathematics as a focus for their research because: a) it is encouraged in mathematics education reform efforts, b) it is incorporated in the open-response elements of the state proficiency exams, and c) it is an area in which middle school students in their districts score very poorly.

Why Writing?

The use of writing assignments in school mathematics started with the "writing to learn" movement in the '80s and continues today as evidenced by the National Council of Teachers of Mathematics' (NCTM) standards document, *Principles and Standards for School Mathematics* (2000). The call from NCTM to make communication an important facet in the mathematics classroom has led to an increase in instructional activities that encourage communication not only between teacher and student, but also among students. The Communication Standard includes being able to organize, communicate, analyze, and evaluate thoughts using the language of mathematics. An essential facet of

[2] Pseudonyms have been used for the four teachers.

communication is writing, which is used in just about every academic subject but is rarely used in mathematics classes. Communication through writing in mathematics classes is generally used in two capacities: journal writing and expository writing. In journal writing, students usually reflect on some activity or respond to a prompt given by the teacher in order to solidify their thinking on some topic or concept. In expository writing, students use writing as an active part of the learning process with in-class writing activities or prompts. For instance, a writing prompt may require students to solve a mathematical problem and then explain their thinking or problem-solving processes. Expository writing activities allow students to use another avenue or representation in their mathematical learning. In effect, writing is communicating and students communicate their understanding to their teachers and to others through these various types of writing activities. It is important to consider both uses of writing in mathematics because each activity has its own benefits, depending on what the teacher wants to accomplish (Birken, 1989; Borasi & Rose, 1989; Cai, Jakabcsin & Lane, 1996; Drake & Amspaugh, 1994).

The writing that students do in mathematics classes is quite different from other classes or disciplines because mathematics is presented as a heavily symbolic discipline. The bulk of student work in mathematics classes consists of symbol manipulation. The symbols are the language of mathematics and ordinary language is used to explain the mathematics. The use of writing to learn mathematics, however, tries to use writing in different capacities of the learning process. In trying to articulate their thoughts in words, the students reflect and internalize, which promotes further learning.

Two studies classified students' writing in order to determine what comprises students' writing. In the first study, Shield and Galbraith (1998) analyzed eighth grade students' writing and developed a coding scheme for content of the writing in order to generate a model of student writing. In addition to developing the coding scheme, they compared the writing samples with the type of writing that occurred in the students' textbook. They identified six features of the students' writing: exemplar, goal statement, kernel, justification, link to prior knowledge, and practice exercises. The most common of these was exemplar in which students gave verbal descriptions of specific examples, diagrams, conventions, and graphs (p.39). In comparison with the students' textbook, Shield and Galbraith found that the writing samples heavily reflected the same type of writing style, which was a focus on procedures and algorithms with little elaboration and written in an authoritative tone (p.45).

In another study, Pearce and Davison (1988) determined the amount, kinds, and uses of writing that teachers employ in junior high school mathematics classes. By looking at student samples and teacher interviews, they classified five types of writing activities: direct use of language (copying and transcribing information), linguistic translation (translation of mathematical symbols into words), summarizing/interpreting (summarizing, paraphrasing, and making personal notations about material from texts or other sources), applied use of language (situations where a mathematical idea is applied to a problem context), and creative use of language (using written language to explore and convey mathematically related language) (p.10). They found that the direct use of language activities were most frequently used.

These studies offer ways of classifying and explaining students' writing in mathematics classes. The researchers recognized that the type of writing that occurs in mathematics classes is different than that of other disciplines and thus needed to be examined further in order to assess the elements of student's mathematical writing. In effect, they discovered how students communicate their knowledge to the teacher through the different types of writing activities.

This account of some of the research in communication and mathematics shows how researchers have partnered with schools in an effort to study the issues that are concurrent with the NCTM standards. The teacher-researchers with whom I worked in the professional development program sought to incorporate similar research ideas into their instruction and thusly into their action research projects.

Methodology

This study/discussion is a meta-analysis of the four teacher-researchers' action research projects. For this discussion, two types of data were collected: audio recordings of meetings and conversations, and documents (from the teacher-researchers, in addition to my field notes). Each data analysis meeting for the teachers' projects was audio recorded and field notes were taken during those meetings. Other conversations regarding the projects were tape recorded as well. The documents that were analyzed included their research proposals, reflections throughout the past year, open-ended surveys, and final papers. I analyzed these tapes and documents using principles of grounded theory (Charmaz, 2000). The emergent patterns and themes in the taped conversations were investigated further and triangulated with the other documents (Janesick, 2000). In this kind of study, these documents are important because they have

cataloged the teacher-researchers' beliefs, values, and experiences (Marshall & Rossman, 1995) throughout the two years of the program. The codes that were developed during data gathering and data analysis were thus further developed into the theory that will be discussed. It is important to note that in keeping consistency with the principles of grounded theory, disconfirming data or negative cases were sought after, but were not found.

Without discussing each teacher's individual projects, I will limit the proceeding discussion to two areas: the experiences of the teacher-researchers with regard to conducting their research, and their experiences with implementing the writing in their classes, including their future research directions.

Data Analysis

The Research Process

The teacher-researchers began their academic year each by writing a research proposal that outlined their research plans for the year. These proposals were complete with research questions, methods, and proposed data collection and analysis. As mentioned before, all four of the teachers implemented writing into their mathematics instruction because they wanted to improve the open-ended response questions on their students' state proficiency tests. The personal goals of the writing projects were best expressed by Joanne and Amber.

> *Joanne: Through writing in mathematics, I hope to change the way students feel about math, help students do better in math, and increase their mathematical understanding.*

Amber: The goal was to supply the students with the appropriate tools for approaching an extended response question.

The teacher-researchers took personal interests in their research questions because of their concern for their students' learning. Seeing their students succeed in mathematics was important to them. The following statements were in response to the question "Why is your [research] question important to you."

Amber: I want to improve scores and I find that students struggle on the open response questions.

Iris: I am looking for some way of making problem solving less threatening in general...to help increase students problem solving capabilities.

Joanne: I am hoping that through writing, communicating students' attitudes and conceptual understanding will improve.

Jean: I am proposing that [writing] will result in a change in attitudes and scores are improved in open-ended response questions.

All of the teacher-researchers expressed concern not only for their students to do better on their tests, but also to help their students learn the mathematics and make it less difficult. These ambitions were reasonable because there is research that supports these views (Borasi & Rose, 1989; Johanning, 2000; Jurdak and Zein, 1998).

One of the larger issues in conducting their research was in organizing their data. Collecting writing samples and test scores for their data was straightforward, but less so was knowing what do with all of it once it was collected. My role became important in this capacity, since I had experience analyzing similar types of data. One aspect of data analysis that I assisted with was in how to analyze pieces of writing. I had done

discourse analysis work prior and shared with the teacher-researchers some techniques of analyzing writing. These discussions led us to talk about criterion-based rubrics and how to grade their students' work accordingly.

All three teacher-researchers that used expository writing strategies in their research utilized a criterion-based rubric in evaluating their data. Jean used a rubric pre-established by her school district that is used to score the standardized tests. Joanne developed her own rubric that she used throughout the year and has written about it (Zupancic & Ishii, in press). Iris and I worked together to revise a rubric she had adapted from her school district's standard in order to make it user-friendly. The only teacher-researcher that did not use expository writing was Amber, who used journal-writing strategies. She too developed a rubric to score the journal entries that was based upon the rubric given to her by the school district. Though the individual rubrics were scored somewhat differently, they all had some common elements. The rubrics addressed issues in writing such as accurate mathematical work, effective explanations, strategies, organization, and logical reasoning.

A common experience in research is dealing with varying amounts of data.

Iris: I have too much quantity, I need more quality.

Here, Iris was referring to the fact that she collected a few writing assignments per week, but felt that they were not quality work, or at least work that she felt was representative of her students' abilities. She expressed her thoughts about giving one question per week and letting students work on them for a few days instead of having multiple writing assignments per week as she did in the beginning of the year.

In one of our data analysis meetings, the teacher-researchers realized that they had collected data that addressed the learning aspects of the research questions such as writing samples and test scores, but had not focused on the attitudinal elements surrounding their research projects. We decided that they should try to either interview their students or give them a survey to address these issues. After Iris and I had given her students a short informal attitudinal survey and had conducted interviews with a few of her students, we shared that process with the other teachers, and discussed the importance of giving informal and brief surveys that would not take up valuable class time. We all participated in helping each other develop their own surveys and interview questions. By the time they were ready to write up their data, everyone had interview data to work with as well.

Once they gave their surveys and collected test scores, Amber and Joanne became aware of the fact that they had some data that they did not know how to organize or analyze.

Amber: I need to get the data in a useful manner.

Joanne: I don't know what to do with these surveys, how do I get them into something that makes sense?

Both Amber's and Joanne's problems were in transferring raw survey data into some kind of chart or spreadsheet that would be useful in their data analysis. We discussed ways of getting raw data into data that can be run through computer programs, spreadsheets, or put into frequency charts.

The main support I provided for the teacher-researchers was as a resource for their research, and data collection and analysis concerns. Some of these concerns were

not unique to conducting research or action research in schools such as conducting interviews or collecting surveys. However, conducting research on writing in the mathematics classroom has different research issues associated with it.

Implementing Writing

The primary reason for the teacher-researchers to implement writing strategies in their instruction was to improve students' scores on the open response questions on their standardized tests. Also, an obvious underlying reason was to improve student learning of mathematical content. The teacher-researchers implemented writing in a variety of ways.

Joanne used writing activities to start off the class period, frequently using them at the beginning of class as a warm-up exercise to focus the students' attention on the mathematics of the day. She used writing prompts that were problem-solving types of questions that the students worked on individually to make sure that everyone attempted the problem. Then she often had them form small groups giving the students the opportunity to share their strategies and solutions with each other, leading to increased student participation and motivation. Since they spent time working on the problems, they were interested in sharing their work as well as seeing the various ways that other students approached the problems. Even if students did not understand how to process the problem or get the answer, they could share how they set up their information or how they attempted to solve it.

Joanne developed a problem-solving format called ODEAR, which is an acronym that helps the students organize their thinking when they write. ODEAR consists of five elements: *Organize, Define, Explore, Answer,* and *Reflect.* When given a problem to

solve, the students use the acronym to help them get started and thoroughly answer their problems.

Iris's employment of writing in her classes was done primarily as in-class activities. She used a prescribed writing process similar to Joanne's ODEAR. Iris's is called EPSE, *Explore, Plan, Solve,* and *Evaluate.* To use this, she would give a word problem on the board and have them solve and write out the problem individually. Occasionally they would compare their work with each other, but generally they worked individually. In one of her lessons, Iris gave a problem and let them work together in groups of four to five. The groups then presented their work to the entire class, so that everyone could see the different solutions. She reported that the students really liked that lesson and she found it beneficial too because she immediately saw what they knew about the mathematical material.

Jean used writing activities both during class and as final thoughts or assignments that encouraged reflection and summarization. One activity in particular that Jean used was the exit ticket, which is a final activity, reflection, or problem that the students would have to complete either before they left the class or moved onto a different subject.

> *Jean: The exit ticket at the end of the class lesson has encouraged students to think about what has been learned in class and encouraged discussion that sometimes does not occur in the classroom due to time.*

She also used prewriting assignments to help create assignments that they share and edit together. This is a way to foster some thinking ahead of time. Using this along with students writing, sharing, and revising their work can lead to clear cohesive pieces of expository writing. In addition to the well thought-out prewriting and writing

assignments, Jean used writing as a way of closing down discovery-type activities. For instance, when she used manipulatives to model fraction arithmetic, then she included a writing activity for students to express what they discovered.

Amber's approach to writing was slightly different than her colleagues'. She used more of a journal-writing format, where she asked students to write about their feelings or attitudes, mathematical processes, and mathematical concepts. The students kept journals or notebooks so that they had records of all of their writing. The students had the opportunity to share their writings with each other that focused on the mathematical procedures and content. Amber periodically collected and provided feedback addressing all the types of journal entries - affective, procedural, and conceptual.

Based upon our research meetings and from the teacher-researchers' reflective writings, some of them had some evaluating difficulties keeping up with the writing. The problem was finding time to respond to the writing.

Iris: I wasn't able to respond to their problems as well as I should have. I should have given them more feedback and let them give each other more feedback.

Since Iris did not use the group sharing of writing the way that some of the other teachers did, her students received limited benefits from reflecting on their writing after receiving feedback whether it be from the teacher or from fellow students.

Amber had a similar challenge in implementing a teaching technique with her students.

Amber: I have found that keeping up on journals can be very difficult especially when the process is new to the teacher... I failed to respond to writing samples in an adequate amount of time.

She reported that the students would have benefited more from the journal-writing assignments had she been able to collect them and provide feedback more often. Since incorporating journal writing was a new teaching technique, it was difficult to adjust to the time constraints and reorganize time usage. Even though Amber felt that she was not able to provide her students with the amount of feedback as she had hoped, she did use the journal-writing assignments to have the students share with each other and provide peer evaluations.

In our final conversations, as well as in the teacher-researchers' writings, I found they concluded that after using the writing activities for a whole school year, there were two aspects of the experience that were of noteworthy benefit to the students and their learning. The greatest benefit was that the use of writing assignments promoted student-to-student discourse, something that usually does not occur in mathematics classrooms. The second benefit that the teacher-researchers identified was that they observed an increase in student motivation, thinking, and understanding from previous years of teaching.

Amber stated that she never intended for the writing activities to accompany discussion of it among students. She planned on using writing as a learning tool that the students would use individually and use the journals for personal reflection and learning. However, the discussion of her students' writing happened by accident when a student volunteered to read hers aloud after they had written about a problem. Amber indulged the student and sharing became a norm of the classroom activity.

The following was from a conversation that we had about using writing and how student-to-student discourse seemed to be a natural consequence of that activity if the teacher allows it.

Amber: I don't necessarily think that employing a writing component in your math class is very beneficial unless you utilize it and discuss [the writing].

Iris made a comment to us that agreed with what Amber discovered about writing in her classes.

Iris: You can't expect writing along to increase their problem-solving abilities...

Amber: ... unless you're doing something with it. In interviews with my students, they indicated that writing about mathematics helped them to understand some concepts better. They also indicated that it was not necessarily the writing that helped but the sharing of the writing and the discussions that came after.

Jean: The student-to-student discourse in my class has promoted conversation and debate about mathematical concepts.

It is not possible to have students discuss their writing all of the time. Even though Iris did not use the writing activities to promote discussions per se, she became aware that through discussion the writing might be used as a technique to encourage classroom discourse. Both Joanne and Jean reported that their students enjoyed explaining their solutions in class, and that they were often eager to share their findings with other students.

Another consequence of using the writing activities along with discourse is that it supports student thinking. Because of the reflective nature of speech and dialogue, discussions among students can be valuable tools for learning (Vygotsky, 1978). Joanne

echoed this position saying that she believed that without discussion to force students to think about their thinking, the writing activities are not that meaningful.

Joanne: My students have learned many things from each other this year, and from themselves. Sometimes they understand better when another student explains the mathematics.

Iris followed with a comment along the same lines about argument and how it advances learning.

Iris: Trying to convince someone you are right through discourse is certainly a form of teaching and teaching is a great way to learn.

Joanne: If students really understand a concept then they should be able to teach and explain it.

It seems as though dialogue is a vital and possibly unexpected aspect of incorporating writing into the mathematics classroom. As students work on mathematics problems and they take the time to write out their solutions, it is natural for them to feel that they should share their solutions with each other and their teachers. This discourse then provides the students with valuable feedback about the way they are thinking about the mathematics. This cycle of thinking and reflection thus promotes more learning.

Among the main benefits of using writing in their mathematics classrooms, the teacher-researchers discovered some other useful results.

Amber: I can honestly say that I feel that I know my students' mathematical ability much better this year than I ever have in the past. I know more about my kids than I ever have any other year.

Joanne: You really find out what they know, even if you have a 'D' student, you find out that that kid really does know a whole lot about math... and it's a shame that the kid's getting a 'D'.

Jean: I sometimes realize that I may have not taught a concept clearly when many of the students have come to the same misdirected conclusion

Iris: I've really learned about what I need to do next year.

These personal benefits of using writing in their classes show that the teacher-researchers learned a great deal from their students by reading and participating in discussion. They learned from themselves by using different teaching techniques and deciding on better ways to foster student learning. They also learned a great deal from each other by participating in our conversations and meetings about the data analysis and debriefing of their action research projects.

Among the many things the teacher-researchers learned not only about their students, but also about themselves is that they learned what they want and/or need to do for the next time they use writing, which for them will be in the next school year. It is important to realize that when trying out new teaching techniques everything might not result ideally the first time. Good teaching techniques take years to perfect, and these teacher-researchers have a sense of they would proceed in the future.

Amber: I want to get with my language arts teacher to see if we can use it a little bit more than what I did this year.

Joanne: I want to try writing activities with my LD (learning disability) students.

Iris: The one thing I wish I could have incorporated into my classroom was the use of discourse. Next time I want to try using this with more discourse and re-writing after they have discussed their solutions.

Amber: I would have the students keep a journal book in the room instead of on loose paper, and respond in an appropriate amount of time.

Jean: Changes that I would like to make would be the rubric that I have used to grade expository essays.(recall that she used the district's rubric and she did not like toward the end of the project)

Joanne: I want to have students grade their own and each other's writing using the [ODEAR] rubric.

After completing these projects with the teacher-researchers, I think they learned wonderful lessons from their own teaching. They also enjoyed the process enough to want to continue the use of writing in their classes, and continue to make improvements in their teaching, which is one of the main goals of conducting action research in the first place.

Concluding Thoughts

This discussion surveyed the experiences and issues that arose from first-time teacher-researchers incorporating writing strategies into their mathematics classrooms. They utilized several types of writing strategies including expository writing, warm-up writing, problem solving, journal writing, and reflective writings. The teacher-researchers discovered several benefits of using the writing in their practice. They found that writing was not only advantageous to the students, but also to the teachers themselves. These results are consistent with research that addresses not only student

benefits, but also for teachers (Borasi & Rose, 1989; Miller, 1992). Students benefited from writing by increasing their thinking and reflection, and having an opportunity to share their writing that, in turn, led to dialogue and discussion with each other as well as the teacher-researchers. The teacher-researchers developed a better understanding of their students' knowledge and conceptions because of the additional opportunities to discuss their thinking and to provide feedback on their writing samples. The ultimate benefit from the writing is that it enables more dialogue between all members of the classroom, which is something that is often missing from mathematics classrooms.

Although there were many benefits to the utilization of writing strategies, the research process for the teacher-researchers was not always a smooth one. They had difficulties with data collection in trying to gather richer and thicker data, rather than simply collecting mass quantities. The teacher-researchers sometimes required help organizing their data and translating it into workable pieces. Some of them were in need of assistance in designing instruments in order to collect survey and interview data. A final hurdle that some of the teacher-researchers encountered was that using a new technique in teaching and collecting data simultaneously is not always easy. It requires diligence and a commitment to the project that can seem overwhelming at times.

This project served as a great learning tool for everyone involved. The teacher-researchers learned about their teaching, as well as potential future directions for their research. They learned about their teaching from using writing, but engaging in action research provided another learning arena for them because they stepped back from their practice and evaluated it systematically. Writing can serve as a learning tool that has the

potential to be extremely beneficial as well as enjoyable when discussions are an integral part of the process.

This meta-analysis gave me the opportunity to evaluate the use of writing in mathematics in action. Engaging in this project allowed me to see the applications of research to the classroom and vice versa. Working with the four teacher-researchers showed me the reality of conducting research in a middle school setting and all of the challenges and enjoyment that can result from it.

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SE067972

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Title: Emergent issues in middle school mathematics action research: A meta-analysis of writing as a pedagogical Strategy.

Author(s): Drew K. Ishii

Corporate Source: The Ohio State University

Publication Date: 10-17-02

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